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A Partnership between Value Engineering and the Diminishing Manufacturing Sources and Material Shortages Community to Reduce Ownership Costs

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PREFACE

The Institute for Defense Analyses (IDA) prepared this document for the Office of the Deputy Under Secretary of Defense, Acquisition and Technology, under a task titled "Total Ownership Cost Reduction." This document partially fulfills the task objective of supporting initiatives related to Reduction of Total Ownership Cost and Value Engineering by describing how the diminishing manufacturing sources and material shortages community can use value engineering to develop better, more innovative solutions to its problems.

The authors of this report would like to thank James R. Vickers and Ina R. Merson of Raytheon Missile Systems for their contributions to this document. Harley A. Cloud of IDA was the technical reviewer for this document.

TABLE OF CONTENTS

LIST OF FIGURES

SUMMARY

Value engineering (VE) is a systems engineering tool that employs a structured, innovative problem-solving methodology to reduce cost and improve quality and performance of Department of Defense (DoD) systems and processes. It develops solutions by eliminating unnecessary functions and establishing new combinations of functions in order to be more responsive to the needs of the customer. Diminishing manufacturing sources and material shortages (DMSMS) is defined as the loss or impending loss of manufacturers of items or suppliers of items or raw materials. Under DMSMS conditions, the resources required to perform a function are increasing, or are about to increase significantly. Commonality between the DMSMS risk management process and the VE methodology is high since VE systematically finds innovative solutions that reduce such costs and increase value.

More specifically, VE is an extremely powerful tool and methodology for (1) identifying a large number of solution options; (2) evaluating their potential for solving the problem; (3) developing recommendations; and (4) providing incentives for the investments needed for successful implementation. Thus, using the VE methodology also provides *greater opportunity* for developing and implementing innovative solutions to DMSMS problems.

As such, VE is ideally suited for use in resolving DMSMS issues. The DMSMS community identifies problems (ideally with plenty of lead time to determine a solution) and the VE tool develops solutions to those problems through function analysis. However the synergies are greater than this. The VE-enabled shared savings with the contractor is also a major factor. This concept provides the contractor with the incentive necessary to make investments that will mitigate DMSMS problems. This paper discusses eight principal DMSMS resolution options and how VE can be used to make a significant contribution to them using real-life examples.

Several broad areas of activities should be pursued to institutionalize the relationship between the two communities. For example, better communication among the communities should be encouraged. The DMSMS community should receive training on VE methods and capabilities. As a consequence, proactive DMSMS management might routinely include the use of VE practitioners before problems become urgent.

Similarly, VE practitioners should more actively interface with the DMSMS community and be better trained in working with DMSMS problems.

There should be extensive outreach to defense contractors and Government and industry program managers as well. Neither DoD logistics program managers nor the logistics support elements of companies with Performance Based Logistics (PBL) contracts have much experience with VE. Senior DoD leadership should be engaged to bring VE capabilities to the attention of the logistics communities in the DoD Components. Once these PBL customers understand the benefits of using VE in support contracts, they will be more likely to promote its use by PBL providers.

Changes to the routine practices and regulations of the DoD contracting community will also help. The examples presented in this document suggest that serious consideration should be given to:

- Changing the Defense Federal Acquisition Regulations (DFARS) to permit longer sharing periods to provide a better opportunity for contractor investments to achieve an adequate rate of return;
- Modifying the hardware-centric approach to the relevant portion of the Federal Acquisition Regulation (FAR); and
- Promoting the use of the Value Engineering Program Requirement (VEPR) clause (FAR clause 52.248-1 Alternate II or III) to provide the contractor with incentives to identify DMSMS options that are most advantageous to the DoD.

A. BACKGROUND

Department of Defense (DoD) systems are normally designed to be operational for 10–20 years or longer. The development time for these systems usually lasts from 5 to 10 years. Thus it is common for these systems to face diminishing manufacturing sources and material shortages (DMSMS) over their life cycles. Consequently, all DoD programs should try to mitigate DMSMS risks to reduce cost and improve defense readiness.

Value engineering (VE) is concerned with reducing the cost to develop, produce, and support DoD systems. It is both a problem-solving discipline and an incentive mechanism for developing approaches to lower ownership cost. As such, there is a natural synergy between VE and DMSMS. DMSMS is a source of ownership cost problems and VE provides a way to develop innovative solutions to these problems.

Sections B and C of this paper provide introductory information about DMSMS and VE, respectively. With that background, Section D then describes the relationship between the VE problem-solving methodology and the DMSMS risk-mitigation process. Real examples of potential VE contributions to DMSMS are provided in Section F. In conclusion, Section G presents ideas for taking advantage of the VE/DMSMS synergies by making the use of VE a routine part of DMSMS management and planning.

B. INTRODUCTION TO DMSMS

DMSMS is defined as the loss or impending loss of manufacturers or suppliers of items or raw materials. DMSMS is a complex issue with at least three basic problems to be addressed:

- ***Technology improvements:*** As new products are developed, the technology used in predecessor products becomes outdated, making it more difficult to maintain the older equipment.
- ***Decreasing demand***: The parts needed to repair products may become more difficult and expensive to acquire because fewer are produced as demand for them decreases.
- ***Non-availability of materials:*** The materials required to manufacture products may no longer be available, or they may be uneconomical to procure.

As products evolve, they require different processes, parts, and technology than their predecessors; however, the earlier versions still need to be maintained throughout their life cycles. As new products become more prevalent fewer parts are available to fix the older versions as the technology, manufacturing processes, and materials become outdated. This is especially true for commercial-off-the-shelf (COTS) parts. Commercial parts availability and performance are dictated by the non-military market. The lapsed time from military program development initiation to completion of the production and support in the field leads to greater numbers of DMSMS problems when using COTS.

DMSMS is closely related to Performance-Based Logistics (PBL), which is a support strategy that places primary emphasis on optimizing weapon system support to meet the needs of the warfighter. PBL specifies outcome performance goals of weapon systems, ensures that responsibilities are assigned, provides incentives for attaining these goals, and facilitates the overall life-cycle management of system reliability, supportability, and total ownership costs. It is an integrated acquisition and logistics process for buying weapon system capability. Generally, PBL contracts are long-term (5–15 years) and require that the provider manage many aspects of product support throughout the life cycle. A properly structured PBL strategy incentivizes the provider to maintain a proactive DMSMS management program to achieve the required performance outcome(s).

Figure 1, extracted from the DMSMS Guidebook,[1] pictures the steps in a DMSMS risk management process.

The first step is identification and notification, that is, quick and concise communication among all stakeholders when a DMSMS case first occurs. If DMSMS management is being done in a reactive mode, communication may be all that can be done. A notice by a supplier of plans to discontinue a part may be the only warning of a DMSMS issue. However, a proactive DMSMS risk management process requires more. *Potential* DMSMS concerns should be continuously monitored so they can be identified and mitigated long before it is necessary to "sound the alarm." This implies keeping track of materials and suppliers to anticipate issues. Although vendor "surprises" cannot be completely eliminated, such an approach maximizes the time to react.

The verification step develops an understanding of the scope and extent of the pending issue from a demand perspective. Facts are gathered so that a sound decision on the appropriate DMSMS resolution option can be determined. Data such as the systems affected and estimates of the demand per system for the part in question must be

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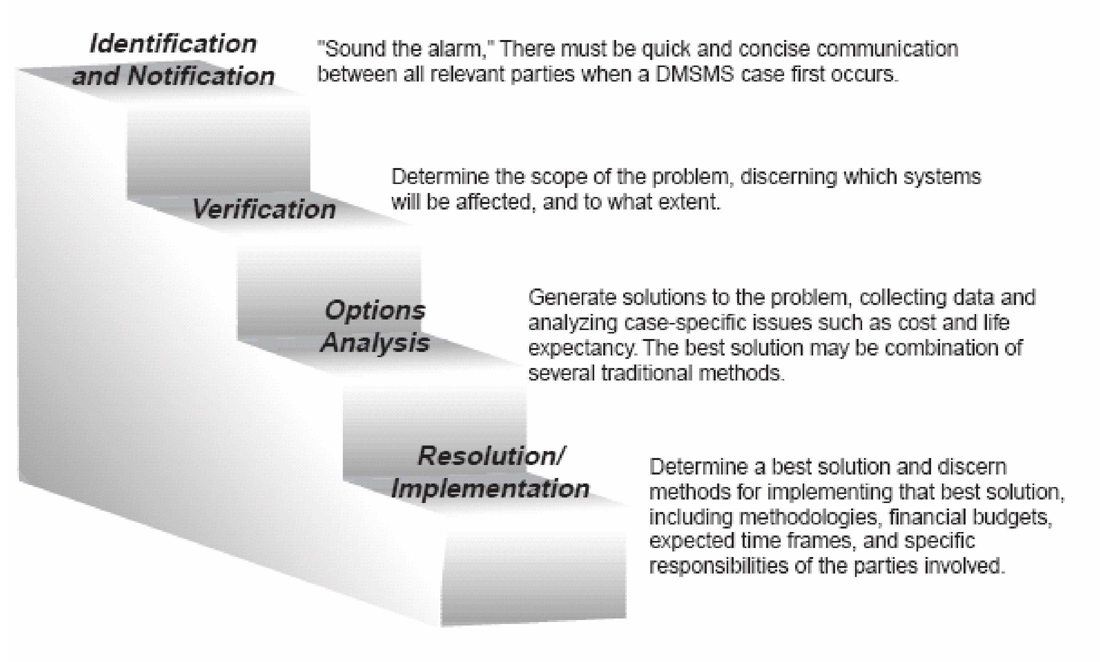
1 Office of the Under Secretary of Defense for Acquisition, Technology and Logistics, "Diminishing Manufacturing Sources and Material Shortages (DMSMS) Guidebook," November 1, 2006. The Guidebook cites the original source of the figure as Air Force Materiel Command DMSMS Program, Case Resolution Guide, Version 2.0," 31 March 2001, available at http://www.gidep.org/data/dmsms/library/crg_2001.pdf.

obtained. Demand is usually estimated on the basis of historical usage. Sometimes these estimates may accurately reflect future usage, but in other cases, where, for example, the effects of an obsolete design cause conditions to change, historical estimates may not be a good predictor. Therefore, understanding the sources of variance and developing both optimistic and pessimistic estimates are helpful.



Source: DMSMS Guidebook, p. 3-1.

Figure 1. DMSMS Risk Management Process

The third step in the DMSMS risk management process is options analysis. The DMSMS Guidebook discusses options ranging from encouraging the existing source to continue production to using Defense Production Act authorities to maintain a domestic source of supply. Case-specific analyses must be conducted to determine the most effective option or combination of options to mitigate the situation. A great deal of data are needed to support this effort. The following information is needed for the item(s) in question:

- The nature of the supply shortage,
- When production is expected to stop,
- The willingness and ability of the supplier to work with DoD in developing mitigation actions,
- The availability of a technical data package, and
- The roles of other pertinent contractors (e.g., a PBL provider).

Information about alternatives is also needed. For example, the following questions should be answered along with an indication of the associated costs, risks, and schedule:

- Are there any alternative sources?
- What would be required to develop an alternative source?
- Is there a known substitute?
- Can a substitute be designed?
- Is a life-of-type purchase a feasible solution?
- What are the interface requirements?
- What kinds of testing and qualification activities are necessary?
- What are the field logistic support issues with alternate components and/or a redesign?
- Is the redesign of a higher-level assembly feasible and desirable?
- Can a needed system performance enhancement be achieved by a DMSMS redesign?

The final step in the process is resolution/implementation. Based on the results of the options analysis step, pros and cons will be developed for different alternatives. Recommendations should then be presented to the decision maker. After a resolution alternative has been selected, implementation begins. Often, responsibilities for implementation will reside with different organizations. Therefore, careful coordination of activities is a necessity.

C. INTRODUCTION TO VALUE ENGINEERING

VE is a systems engineering tool that reduces cost, increases quality, and improves mission capabilities across the entire spectrum of DoD systems, processes, and organizations. VE employs a simple, flexible, and structured set of tools, techniques, and procedures that challenge the status quo by promoting innovation and creativity. VE has been in use since World War II when material shortages necessitated finding substitute materials. It has been a DoD requirement since 1963.

The VE methodology is applied in a "value study" conducted in eight sequential phases (which may overlap in practice) called the job plan.[2] The phases are as described in the following subsections.

[2] The material in this section has been adapted from IDA Paper P-4114, "Value Engineering Handbook," Jay Mandelbaum and Danny L. Reed, September 2006.

1. Orientation Phase: Refine the Problem and Prepare for the Value Study

Although a problem area may have been identified, the value study has a far greater likelihood of success if ample preparation time has been devoted to (1) determining what aspects of the problem will be addressed in detail and (2) preparing everything needed for the analysis itself. Therefore, the orientation phase is used to:

- Identify the specific issues to be discussed.
- Assess the potential gains for resolving each of these issues.
- Prioritize the issues.
- Draft a scope and objective for the value study.
- Establish evaluation factors.
- Determine the composition of the value study participants.
- Collect the data needed to perform the value study so it is ready for the study team.
- Prepare logistically for the value study.

2. Information Phase: Finalize the Scope of the Issues To Be Addressed, Targets for Improvement, and Evaluation Factors While Building Cohesion among Value Team Members

In many respects, the Information Phase completes the activities begun in the Orientation Phase. This work is normally carried out in the workshop setting and is therefore usually the first opportunity for all team members to be together. Consequently, it is important to use the Information Phase to motivate the team to work toward a common goal. Finalizing the scope of the issues to be addressed, targets for improvement, evaluation factors, and data collection are ideal endeavors for building that cohesion.

3. Function Analysis Phase: Identify the Most Beneficial Areas for Study

Function analysis is central to and the distinguishing feature of the VE methodology. A function is composed of an action verb (that answers the question “What does it do?”) and a noun (that answers the question “What does it do this to?”). This phase uses a five-step process. as follows:

- Determine the functions for every element of the product or process that consumes resources.
- Classify the functions into basic (i.e., the primary purpose) and secondary functions.

- Develop relationships among the functions that provide detailed answers to the questions of how and why the functions are performed.
- Estimate the cost of performing each function.
- Determine the best opportunities for improvement by comparing the lowest possible cost for performing that function to the actual function cost.

4. Creative Phase: Develop a Large Number of Ideas for Alternative Ways To Perform Each Function Selected for Further Study

Creative problem-solving techniques are an indispensable ingredient of effective VE. By using the expertise and experience of the study team members, some new ideas will be developed. The synergistic effect of combining the expertise and experience of all team members will lead to a far greater number of possibilities. Key elements in this process are as follows:

- Discourage creativity inhibitors.
- Establish ground rules.
- Generate alternative ideas using brainstorming or other similar techniques.

5. Evaluation Phase: Refine and Select the Best Ideas for Development into Specific Value-Improvement Recommendations

Ultimately, the decision-maker should be presented with a small number of choices. In the Creative Phase, there is a conscious effort to prohibit judgmental thinking because it inhibits the creative process. The Evaluation Phase must critically assess all the alternatives to identify the best opportunities for value improvement. This phase is not the last chance to defer ideas; detailed cost-benefit analyses conducted in the Development Phase lead to the final set of choices presented to the decision-maker. The following lists the activities in the Evaluation Phase:

- Eliminate low potential ideas.
- Group similar ideas.
- Establish idea champions.
- List the advantages and disadvantages of each idea.
- Rank the ideas.
- Select ideas for further improvement.

6. Development Phase: Determine the "Best" Alternatives for Presentation to the Decision-Maker

In the Development Phase, detailed technical analyses are made for the remaining alternatives. These analyses form the basis for eliminating weaker alternatives. Steps in this phase are as follows:

- Conduct a life-cycle cost analysis of each remaining alternative.
- Determine the most beneficial alternatives.
- Develop implementation plans identifying the necessary actions to be taken.

7. Presentation Phase: Obtain a Commitment To Follow a Course of Action for Initiating an Alternative

A presentation to the decision-maker (or study sponsor) is made at the conclusion of the workshop. This presentation is normally the first step (not the last step) in the approval process. Typically, a decision to implement is not made at the time of the briefing. Additional steps include:

- Answering additional questions.
- Collection of additional data.
- Review of supporting documentation.
- Involvement of other decision-makers.

8. Implementation Phase: Obtain Final Approval of the Proposal and Facilitate Its Implementation

Activities in this phase are not unique to VE. They include:

- Prepare a written report.
- Enhance the probability of approval by preparing the organization for change.
- Monitor progress.
- Expedite implementation with assistance from the VE study team.

VE has its own unique implementation mechanisms. Final decisions resulting from this process are implemented through both Value Engineering Proposals (VEPs) and Value Engineering Change Proposals (VECPs).

A VEP is a specific proposal developed internally by DoD personnel for total value improvement from the use of VE techniques. Since VEPs are developed and implemented by Government personnel, all resulting savings accrue to the Government. A VEP can also be the result of a technical support contractor effort if it is funded by the Government specifically to conduct a VE study on a contract to which it is not a party.

A VECP is a proposal submitted to the Government by the contractor in accordance with the VE clause in the contract. A VECP proposes a change that, if accepted and implemented, provides an eventual, overall cost savings to the Government and a substantial share in the savings accrued as a result of implementation of the change for the contractor. It provides a vehicle through which acquisition and operating costs can be reduced while the contractor's rate of return is increased.

D. RELATIONSHIP OF THE VE METHODOLOGY TO THE DMSMS RISK MANAGEMENT PROCESS

Figure 2 shows the correspondence between the phases of the VE methodology and the steps in the DMSMS risk management process. Both processes attempt to take a problem from identification though the implementation of a solution. However there is a great deal of synergy between the two processes and less overlap than the figure implies.

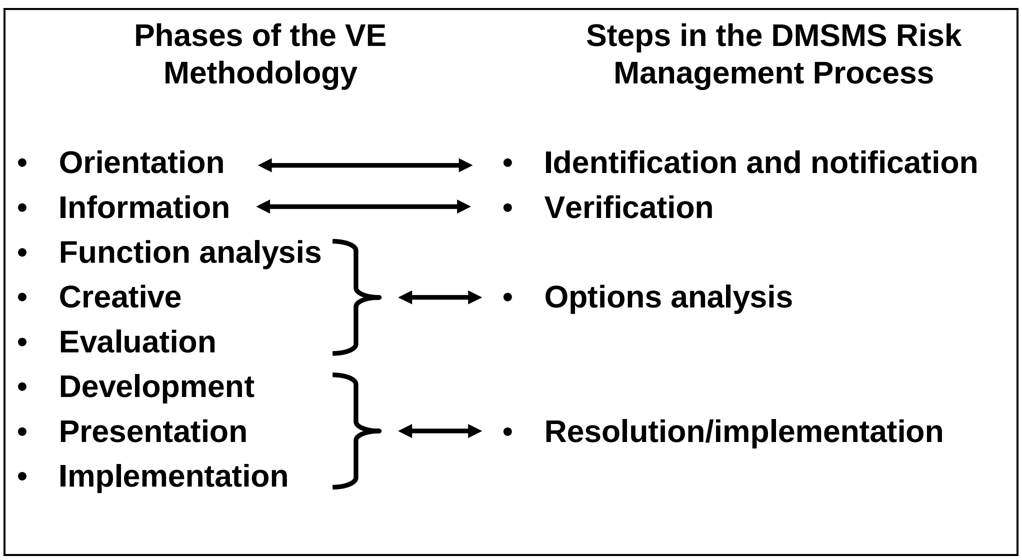


Figure 2. Correspondence between VE Methodology Phases and DMSMS Risk Management Process

VE is a problem-solving discipline. As such, organizations use VE practitioners to help determine solutions to the process and product-related issues they face. Problem identification is the critical first phase of the VE methodology. DMSMS represents a class of problems common to acquisition and logistics organizations. As such, the DMSMS community is a source of problems where there is an opportunity to determine and implement VE-derived solutions.

The DMSMS verification step and the VE Information Phase are similar; they both finalize the scope of the problem. However, the VE methodology has the potential to enhance the DMSMS approach. While DMSMS efforts are more ad hoc, the VE methodology is usually applied by a study team in a structured workshop environment. Therefore, the VE Information Phase also begins building cohesion among study team members. Such an environment leads to a working relationship more conducive to finding optimal solutions to problems.

The DMSMS options analysis step has the same objectives as the VE Function Analysis, Creative, and Evaluation Phases. Once again, the use of VE may enhance these efforts by adding structure, robustness, and rigor to the process. Function analysis is a comprehensive technique for dissecting a problem into its most basic elements and then methodically determining the most beneficial areas for further analysis. Creative brainstorming in a professionally facilitated environment leads to the largest possible number of resolution ideas to be evaluated.

Finally, the VE Development, Presentation, and Implementation Phases correspond to the DMSMS resolution/implementation step. While these activities are somewhat routine, VE allows for its own unique and flexible implementation options.

The following real example illustrates the application of VE to a DMSMS situation in the Navy.

Navy's RIM-7 Sea Sparrow Missile Example
Application of VE to a DMSMS Situation

The Navy's RIM-7 Sea Sparrow surface-to-air missile is a radar-guided missile with a high explosive warhead. The Navy uses the Sea Sparrow missile aboard ships for surface-to-air anti-missile defense. The Evolved Sea Sparrow Missile (ESSM) is an international cooperative upgrade of the RIM-7 NATO Sea Sparrow Missile. ESSM provides self-defense battlespace and firepower against high-speed, highly maneuverable anti-ship missiles. ESSM brings transformational anti-ship missile defense capabilities to the naval fleets of the United States and its NATO and other allies. The missile was developed for the U.S. Navy and nine of the other 11 member nations of the NATO Sea Sparrow Consortium.

A missile safe and arm fuze prevents an unintended launch and, once launched, arms the warhead when the proper stimuli (e.g., speed, gravitational force) are received. The ESSM design called for an obsolete mechanical safe and arming fuze. Since highly skilled artisans were needed for the manufacturing process, and much of the world fuze market had adapted electronic fuzes, the number of suppliers was limited. Consequently, the mechanical fuzes were expensive.

The contractor applied the VE methodology and proposed a VECP to replace the mechanical safe and arm fuze with an electronic one by adapting an electronic safe and arm fuze from the Sidewinder missile. Making a change of this nature was not a simple proposition; it would require extensive and costly testing resulting in significant nonrecurring costs. However, the contractor was able to develop a VECP that offset the development and implementation costs and still resulted in significant savings for both the Navy and contractor to share.

Although development and implementation costs were $1,873,911, and took approximately 2 years to offset, total recurring cost savings equaled $6,832,000, which, when spread over the 1,600 units involved, resulted in a net savings per unit of $4,270. These savings were shared equally between the Navy and the contractor.

E. POTENTIAL VE CONTRIBUTIONS TO DMSMS

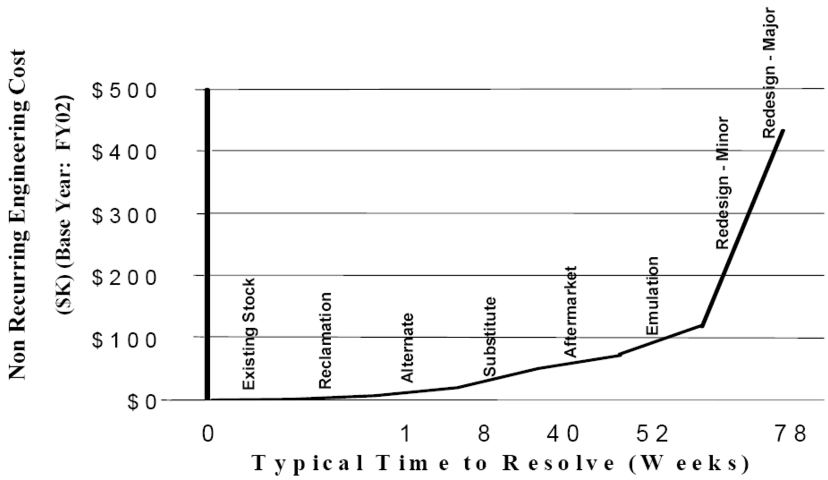
VE can make a significant contribution to DMSMS in several ways. By incentivizing Government participants and their industry partners to increase their joint value proposition in achieving best value solutions as part of a successful business relationship, VE provides businesses with a strong profit-based incentive for using its skilled engineering workforce to mitigate DoD's DMSMS issues. Through the concept of shared savings, VE rewards contractors for making investments in DMSMS resolution options. In addition, the use of VE allows the DoD to spread non-recurring engineering costs over time, making them far easier to fund. Finally, the creative elements of the VE methodology are designed to elicit innovative approaches to problem solving that might not otherwise be considered.

The benefits of applying VE to DMSMS issues are realized regardless of the DMSMS management approach being taken. The use of the VE methodology typically leads to innovative solutions that can be rapidly put in place.

When a program takes a proactive approach to DMSMS, a better solution can be achieved quicker. While a PBL contract normally makes the contractor responsible for DMSMS planning and management, the contractor is no incentivize to look for the best value solution for the Government. Use of PBL does *not* obviate the need for VE. For example, if the PBL contract is for time and material, the Government will pay for the resolution of the problem. Without VE, the contractor will select an approach that optimizes its profit and minimizes its risk from the current PBL contract. That may mean that the contractor will take actions to maximize availability of supply regardless of cost. If the PBL contract is fixed price, the contractor will take a similar approach because future years (which are awarded as contract options) are not normally priced. VE changes the business case by providing the proper incentives for the contractor to adopt an approach more beneficial to the Government in the long term. VE also is more likely to find solutions with other collateral benefits because its methodology is designed to identify a broad range of potential solutions that have impact beyond the immediate problem at hand.

F. EXAMPLES OF VE APPLICATION TO DMSMS RESOLUTION OPTIONS

The DMSMS Guidebook describes numerous DMSMS resolution options. This paper discusses eight principal options (existing stock, reclamation, alternate source, existing substitute, aftermarket, emulation, minor redesign, and major redesign). Figure 3 displays the expected non-recurring engineer costs to implement each option and the typical time needed to resolve the issue (based on an analysis of 181 DMSMS parts, many in the electronics area).



Source: DMSMS Guidebook, p. 4-11.

Figure 3. Time to Resolve and Cost of DMSMS Resolution Options

The subsections that follow describe how VE can enhance these DMSMS resolution options. These sections contain real examples to illustrate the power of VE in each case. Examples include both VEPs and VECPs. Although some of the examples may not apply to a DMSMS problem per se, the situations are analogous. In every case, VE was used to find another way to acquire expensive, hard to obtain parts in the same way that DMSMS approaches look for alternative ways to acquire potentially unavailable items or materials.

1. VE Contributions to an Existing Stock Approach

An existing stock solution to a DMSMS problem is one where the *current* supplier utilizes *on-hand* inventories or agrees to continue to produce the item in question. We discuss the former situation first where a large quantity purchase is made in one of two ways:

- A life-of-type purchase procures a sufficient quantity of the DMSMS part to support full production plus repair for the expected life cycle of the system.
- A bridge purchase procures enough of the DMSMS item to meet demand until another solution is implemented.

While this option is often used, there are drawbacks associated with it. Costs for material management including packaging, storage, transportation, shelf life, and upkeep of the inventory must be considered. In addition, it is difficult to estimate demand accurately, especially for a life-of-type purchase. Frequently, items are retained in the operational inventory well beyond their originally expected life. When that occurs, the life-of-type purchase could be inadequate. On the other hand, if too many are purchased, there is waste associated with the excess inventory.

Value engineering has the potential to incentivize the contractor to perform the material management function and solves short-term budget problems associated with a quantity purchase, as shown in the following real example for radomes for the Standard Missile.

Navy Standard Missile Example of VE Contributions to DMSMS
Using an Existing Stock Resolution Option

The Standard Missile is a surface-to-air air defense weapon. Its primary mission is fleet area air defense and ship self defense and it has a secondary anti-surface ship mission. The radome is a dome that covers the radar on the outside of the missile. There are few radome suppliers because of the complexity involved in finishing them. Radomes must be capable of withstanding high heat and acceleration while allowing signals to penetrate without distortion.

Due to reduced program funding, the Navy halved its Standard Missile procurement rate. Radomes are a high-cost item with large lot charges under this particular missile program acquisition. If the radomes were to be purchased on the revised procurement schedule, the unit price would increase by 50 percent due to production slow down. Because radomes do not change, the Navy wanted to make a quantity purchase to reduce the overall cost. In that way, the radome supplier would be able to level load production to the quantities required for succeeding fiscal years. It would also optimize manufacturing setup time, allowing savings to be passed to the contractor. However, the Navy did not have the resources to pay for the quantity purchase in the current fiscal year.

The contractor had the latitude to use its own funds to make the quantity radome purchase without using the VE clause. However, there would be no likelihood for a return on investment, since, based on FAR pricing principles, the contractor would be required to sell them back to the Navy at the price paid. Meanwhile, the contractor would have incurred inventory holding costs and lost opportunity costs. Use of VE enabled the contractor to make the quantity purchase and sell future radome lots back to the Navy at the lower bulk-buy price, thus leading to significant savings.[3] This particular case led to a total savings of $1,153,500 shared equally by the contractor and the Navy.

In some cases, the supplier may agree to continue production of the DMSMS part. If costs remain competitive, there are no special or unique VE implications unless the

3 A mistaken belief is that a VECP requires a change in a specification. It does not; it requires only a change in the contract. The change could be a contract modification for a business arrangement authorizing the VECP and agreeing on sharing future savings without any technical change to the configuration baseline. That was the case in the radome example where the contract contained the former military standard on configuration management. As such, it required the VECP to be submitted on DD Form 1692, “Engineering Change Proposal.” On Block 30 of the form, Configuration Items Affected, it listed, “None.” On Block 31, Effects on Performance Allocations and Interfaces in System Specification, it listed, “This change will have no effect on the end item’s system performance. This Value Engineering Proposal simply allows us to take advantage of the substantial cost savings obtained by the multi-year contract that [*the contractor*] has negotiated.”

supplier uses VE to improve production. Unfortunately, that is not always the case. The supplier may charge a premium price for continuing production of a marginally profitable (or unprofitable) item over an indefinite period. This situation typically drives the DoD to make a quantity purchase as described above.

There is one additional situation where VE may contribute to the existing stock DMSMS approach—the start up of an inactive production line for an item. Situations arise where the Government pays the contractor to store old production equipment, test equipment, components, and so on, in case there is a need to restart production. For example, this was done for the Phoenix Missile. If the Government were to exercise such an option, there would be many opportunities for VE along the lines discussed in this paper.

2. VE Contributions to a Reclamation Approach

A reclamation solution examines marginal or out-of-service equipment or supplies as a potential source of DMSMS parts. Another reclamation possibility is equipment that is in a long supply, perhaps as a result of a planned product improvement or modernization effort where baseline equipment could be cannibalized to address a DMSMS shortfall.

One potential drawback to reclamation is the condition of the reclaimed parts. They may be unserviceable or damaged. Also, unless very unusual circumstances (e.g., extremely low demand) surround the DMSMS issue, a reclamation effort probably represents only a short-term solution.

Value engineering can play an important role in making reclamation feasible, as shown in the example below for the reclamation of M106 8-inch high-explosive artillery projectile scrap steel.[4]

[4] This example was adapted from the Army’s FY 2006 special VE award nomination.

Army Artillery Example of VE Contributions to DMSMS
Using a Reclamation Approach

The M795 is a 155-millimeter high-explosive artillery projectile with a high-fragmentation steel body. It provides increased effectiveness against major ground-force threats at greater ranges for anti-personnel and anti-materiel targets when compared to older 155-millimeter projectiles. Because of a world-wide scrap steel shortage, the M795 program contractor was finding it difficult to maintain a single source for M795 steel.

A VE study was initiated to develop a process to reutilize the steel from a large stockpile of surplus M106 8-inch projectile shells stored openly at McAlester Army Ammunition Plant. The steel could not be reclaimed directly since the projectiles contained trace amounts of explosives. The M106 projectiles were scheduled for demilitarization.

As a result of this study, a process was developed to decontaminate and mill the surplus M106 projectiles to reclaim the steel. This steel was then used as a constituent in the raw material for the manufacture of the M795 projectiles. M795 production costs were decreased because the cost of the process to provide the raw material needed for production was below the purchase costs on the open market. In addition to the benefits to the M795 program, this VE effort reduced the demilitarization stockpile, reduced demilitarization costs, and eliminated the hazardous open-storage of M106 projectiles at McAlester Army Ammunition Plant. Total cost avoidance savings in FY 2006 for the 197,000 projectiles processed amounted to $9.2 million.

3. VE Contributions to an Alternative Source Approach

The term “alternative source” is used in many different contexts. For example, there may be an alternative source for an aftermarket or reverse-engineered version of a product. These two situations are discussed in the next two subsections. Because Figure 3 shows that this resolution option has relatively low cost, this paper specifically limits the alternative source option to items currently in production that are form, fit, function, and interface (F3I) qualified replacements such as a superseding part listed in a specification or standard.

Analytically, this approach is similar to the existing stock alternative. The principal difference is the need for some limited engineering investigations and F3I testing. The drawbacks are similar as well. The new supplier may charge a higher price, and there is no guarantee how long the new supplier will continue producing the part.

In addition to the benefits shown for the existing stock approach, VE may also play a role in increasing the efficiency of the new supplier’s production process.

4. VE Contributions to an Existing Substitute Approach

An existing substitute item is in fact a different part that is *currently* being produced for a different application. However, an existing substitute item is (or can be made) capable of performing fully (in terms of form, fit, and function) in place of the DMSMS item. In some cases, non-recurring engineering expenses will be incurred to achieve this. A drawback of this approach is that the resolution may be temporary if market conditions do not have a favorable outcome for the new source. In addition, expenses will have to be incurred for qualifying and testing the replacement item and the unit cost may be higher.

Value engineering function analysis identifies viable options for items to be used as an existing substitute and incentivizes the prime contractor to invest in them. This area represents probably the most prevalent use of VE for DoD weapon systems. The following example illustrates the point.

Navy Phalanx Example of VE Contributions to DMSMS
Using an Existing Substitute Approach

The Phalanx Close-In-Weapon-System is a fast-reaction, rapid-fire 20-millimeter gun system that provides Navy ships with a terminal defense against anti-ship missiles and fixed-wing aircraft that have penetrated other fleet defenses. It can also be used against small gunboats, standard and guided artillery, and helicopters. Phalanx uses advanced radar and computer technology to locate, identify, and direct a stream of armor-piercing projectiles to the target. A contract was awarded to retrofit Phalanx with a manual controller to direct fire against targets of opportunity.

Using the function analysis aspect of the VE methodology, the contractor identified an opportunity to replace a military standard fixed-hand controller (similar to a joy stick) with a derivative of a commercial unit, not built to military standards. On its own initiative, the contractor worked with the commercial source to produce a modified unit and tested the unit against the requirements for the military standard version. Based on the test results, the contractor had confidence that the commercial derivative would meet all of the technical requirements at a lower cost. Therefore the contractor submitted a VECP to replace the standard military controller with ruggedized commercial derivatives. The military standard controller would cost $7,600, while the commercial derivative was only $2,100. Since each gun required three controllers, the net savings would be $16,500 per system. Approximately $2 million in savings were shared by the Navy and the contractor. Eventually, the Navy may save more than $9 million if the idea is applied to all ships. In addition, the VECP provided for earlier implementation of the improved system.

5. VE Contributions to an Aftermarket Approach

A DMSMS aftermarket solution is one in which the original equipment manufacturer authorizes the assembly of an obsolete part. An aftermarket source for a product is one that used the drawings (or technical data package if available) and the specifications provided by the original equipment manufacturer or prime contractor to produce an aftermarket version of the DMSMS part.

Aftermarket sources are a viable DMSMS solution because a smaller company might undertake production that is no longer sufficiently profitable for a larger company. The DoD is often able to reduce its costs by using aftermarket sources. With two or more suppliers, competition typically leads to lower cost. In addition, a smaller company (with lower overhead) may be able to produce an item less expensively than a larger company.

As was the case with substitute items, a drawback of this approach is that the resolution may be temporary if market conditions do not have a favorable outcome for the new source. In addition, non-recurring engineering expenses will be incurred for building and testing the new line and ensuring part qualification and certification to meet requirements of form, fit, and function. Finally, the unit cost may be higher.

Value engineering enables the development of viable aftermarket sources. In the first of three examples that follow, an aftermarket source for the Air Force's Advanced

Medium-Range Air-to-Air Missile (AMRAAM) Inertial Reference Unit (IRU) was developed from scratch based on the original requirements; interface constraints; form, fit, and function specifications; and help from the prime contractor.

Air Force AMRAAM Example of VE Contributions to DMSMS
Using an Aftermarket Approach

The AIM-120 Advanced Medium-Range Air-to-Air Missile is a fire-and-forget air-to-air missile capable of attacking beyond-visual-range targets. In the AMRAAM missile, the IRU accurately measures the missile vertical velocity and position enabling in-flight steering and targeting adjustments. Originally, there was only one source for this expensive item. The contractor was aware that others were interested in furnishing this item, so the contractor provided the requirements and helped encourage others in the development of the IRU.

In this example, the contract contained a mandatory VE program and the Government recognized the value of having a second source for the IRU. Even though approximately $4 million in non-recurring engineering costs were required, the effort was well worth it. These efforts initially saved $2,000 per unit, but more importantly, without the addition of a second source through the VECP, the price of the IRU would have probably increased. The potential savings cannot be accurately estimated but are expected to be substantial.

The second example is theoretical. It was originally suggested by the Defense Logistics Agency;[5] the idea has been updated for this paper.

A Potential VE Contribution to DMSMS
Obtaining Qualified Aftermarket Sources

Many original equipment manufacturers are not interested in supporting low dollar or low volume items after production is completed, especially when process equipment is aging and updating it cannot be justified. At a minimum, the cost per item would increase significantly without competition. If the contractor were to stop producing the item, the Defense Logistics Agency (DLA) would have to find and qualify a new source—a process that usually results in high initial startup cost as a result of qualification testing to verify the new source's technical data.

VE can be used as part of an alternative approach. If DLA were able to provide technical data packages (TDPs) for competitive procurements and additional manufacturing sources, costs would drop considerably. For contracts where competition has been introduced, DLA has observed an average price reduction of 47 percent. Under VE, the Government could acquire technical data rights from the contractor as a VECP. The contractor providing the technical data would share in any price reductions achieved by the Government as a result of using the TDP in competition. Based on the 47-percent savings figure, the contractor might get 20 percent of the future sales price as its share of savings on a collateral basis for a negotiated time period. To ensure the contractor is compensated for the TDP, part of the VE settlement might be a 5-percent collateral share of future sales if only one company bid. In either case, DLA would not have to incur the whole expense of developing and qualifying a new source.

The third example is one in which VE plays a role in identifying an aftermarket provider for a service. The following shows a short-term solution for the repair and testing of the Army's M270 rocket launcher test equipment.[6]

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[5] Office of the Under Secretary of Defense for Acquisition and Technology, "Final Report of the Process Action Team on Value Engineering Change Proposals," July 1997.

[6] This example was adapted from the Army's FY 2006 VE award nomination for an individual.

Army Rocket Launcher Example of VE Contributions to DMSMS
Using an Aftermarket Source for a Service and Reclamation

The M270 launcher is a self-propelled armored rocket and missile firing platform. Its Launcher-Loader Module (LLM) contains a built in self-loading system. Each launcher has the onboard capability to receive a fire mission, determine launcher location, compute firing data, orient on the target, and fire. A fire control solution is applied to the LLM via the Stabilization Reference Package (SRP)/Position Determining System (PDS) and the LLM Launcher Drive System. The DMSMS situation arose from outdated test equipment. After an upgrade to the SRP module, the contractor informed the Government that the existing Government-furnished test equipment would also require upgrading at a cost of $1.9 million.

The Army then conducted a VE study to reduce or avoid that cost. The VE study analyzed the functions being performed and suggested an alternative approach. The study determined that the NATO Maintenance and Supply Agency could provide the required testing and repair of the SRP, with the exception of the gyro, a problem that was solved by using excess gyros from decommissioned M270s. The solution is short term because replacement of the M270 by the Army's High Mobility Artillery Rocket System will be completed by fiscal year 2009. Total 3-year savings for the Government was $1.9 million.

6. VE Contributions to a Reverse Engineering[7] Approach

The reverse engineering resolution option seeks a producer to obtain and maintain the design, equipment, and process rights to manufacture a replacement item where no drawings are available. In this case, the new manufacturer uses the item itself to devise a method to produce a copy of the original item with sufficient fidelity to meet F3I requirements. Reverse engineering discovers the design principles of the part by analyzing its structure, function, and operation. No support is provided from the original equipment manufacturer.

As was the case with substitute items, a drawback of this approach is that the resolution may be temporary if market conditions do not have a favorable outcome for the new source. In addition, non-recurring engineering expenses will have to be incurred for designing, building, and testing the replacement item and ensuring part qualification and certification to meet requirements of form, fit and function.[8] The new unit cost may be higher than the original item, and there may be issues of intellectual property rights.

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[7] Figure 3 uses the term "emulation." For this paper, we generalize the situation to include all reverse engineering solutions.

[8] Note that reverse engineering cost can be less than costs incurred in trying to manufacture an item from a TDP. Often, some manufacturing subtleties are not documented in the drawings or the TDP, or the TDP could be obsolete.

Value engineering function analysis identifies viable options for reverse engineering parts. The following example is based on a real VE application that has not been finalized. Therefore, some specific details are omitted.

Missile Example of VE Contributions to DMSMS
Using a Reverse Engineering Approach

A defense missile contractor had a sole-source subcontractor for a costly warhead. The subcontractor was having problems meeting "insensitive munitions capability" requirements for the warhead to not explode in a fire or if dropped. With the cooperation of the Government, the contractor submitted a VECP to develop an alternative, and less expensive, source for the warhead by reverse engineering. Since a different manufacturer is now being used, the performance of the warhead's insensitive munitions capability will also be improved since this manufacturer will use a different process for making the explosive portion of the warhead.

Approximately $12 million is being invested to develop the new source. Although savings of $15,000 per warhead is expected, the development of the second source makes this VE change and development of a second source even more valuable. Without the competition from another source, it was expected that the price of the warhead would have continued to escalate as it had in the past since the single source had no incentive to control costs.

7. VE Contributions to a Redesign Approach

As a resolution option, modification or redesign of the item is used to either eliminate the need for the part in question or replace it with another. Redesign may occur at many levels.

- The DMSMS part itself,
- The next higher level configuration item,
- An entire subsystem, or
- The end item itself.

Non-recurring engineering expenses for building and testing the new production capability and ensuring qualification and certification to meet requirements increase with the scale of the redesign effort. Minor redesign treats the DMSMS problem discreetly by redesigning only at the level needed to solve the immediate problem.

Value engineering function analysis identifies viable minor redesign options. The following example illustrates a minor redesign for an Army Microclimate Cooling Unit.[9]

> **Army Microclimate Cooling System Example of VE Contributions to DMSMS**
> ***Using a Minor Redesign Approach***
>
> The Microclimate Cooling System reduces heat stress to Army helicopter crewmen in chemical, biological, or hot weather environments. It features a vest worn as an undergarment beneath chemical protective clothing or other clothing. The Microclimate Cooling Unit is an autonomous vapor compressor system that chills water and pumps it through small tubes embedded in the vest.
>
> A VE study was initiated because of the high cost, unsatisfactory performance, and impending obsolescence of the analog controller for the unit. The study found that a much cheaper digital controller could be designed to perform the functions of the analog unit, while also providing valuable diagnostic information that the analog unit could not provide. A VECP was developed to make the replacement. In addition to reducing cost, acquisition lead-time dropped from 28–32 weeks to 14–18 weeks and the digital unit is approximately 0.19 pounds lighter than the analog controller. The Government reported VE savings of $1,075 per unit. Three-year savings is estimated to be $230,000 with a potential for an additional $8,000,000 savings on future contracts,

Another example illustrates a minor redesign for the Army's Bradley Fighting Vehicle.[10] The redesign involved the use of different materials. In that sense, this example could also be classified as an existing substitute, where one material (rather than one item) was substituted for another. Such dual classifications are not unusual.

> **Army Bradley Example of VE Contributions to DMSMS**
> ***Using a Minor Redesign Approach***
>
> The Bradley Fighting Vehicle is a fully armored, fully tracked vehicle designed to carry mechanized infantry into close contact with the enemy and to provide fire cover to dismounted troops and to suppress enemy tanks and fighting vehicles. High operations and maintenance costs were being incurred for replacement of the Bradley's high-performance track assembly bushing.
>
> A VE study was performed to determine another way of accomplishing the same function. As a result, a VECP was developed to redesign the bushing by changing its composition to a new, more durable compound that reduced the replacement frequency. As a result, the field service life of the Bradley's track assembly was extended and replacement costs were saved. Overall VE savings are $2,079,000.

From a definitional perspective, it is sometimes hard to differentiate minor redesign from major redesign. The following example deals simultaneously with two somewhat *independent* parts of the Firefinder radar that were experiencing obsolescence issues.[11] On one hand, this example could be construed as a major redesign because of the scope

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9 This example was adapted from the Army's FY 2007 VE award nomination for a contractor.

10 This example was adapted from the Army's FY 2006 VE award nomination for a contractor.

11 This example was adapted from the Army's FY 2007 VE award nomination for a team.

of the combined effort involved. On the other hand, each part could have been dealt with as a separate minor redesign.

Army Radar Example of VE Contributions to DMSMS
Using a Minor Redesign Approach

The AN/TPQ-37 Firefinder radar is designed for long-range detection and tracking of incoming artillery and rocket fire to determine the point of origin for counterbattery fire. The radar's legacy transmitter and radar processor were both experiencing issues with obsolescence and systemic failures. These failures hindered the radar's mission effectiveness and readiness in combat. Manpower and spare parts resources were required in large amounts to keep the systems maintained.

The Army conducted its own VE study to find alternative ways to perform the radar transmitter and processor functions. The study resulted in upgrading the radar with a redesigned electronic power amplifier module to replace the legacy transmitter and a new redesigned radar processor. Incorporating these new components improved the system's reliability, availability, and maintainability. These improvements provide large savings in operations and support costs, which far outweigh the costs to upgrade the radar. A 3-year cost avoidance of $102,784,600 was achieved.

As a resolution option, major modification or redesign of the item eliminates the DMSMS issue while simultaneously dealing with much larger-scale changes to the system. Such an effort will significantly improve performance.

Value engineering function analysis systematically identifies economically viable opportunities for major redesign when there is a high degree of interdependence. The following example represents a major redesign of the Air Force's AMRAAM missile. The range correlator represented about 15 percent of the cost of the missile. Its redesign affected nearly every aspect of the missile.

Air Force AMRAAM Example of VE Contributions to DMSMS
Using a Major Redesign Approach

Early in its initial production, the basic AMRAAM missile used an Analog Range Correlator. The unit was scheduled to be replaced by an enhanced Digital Range Correlator as a pre-planned product improvement when electronic miniaturization became more prevalent and less expensive. However, with implementation several years in the future, the contractor was faced with producing the missile using a very difficult to build and extremely sensitive Analog Range Correlator.

In view of these manufacturing source difficulties, the contractor used VE to propose implementation of an Interim Digital Range Correlator that functioned as a replacement for the existing Analog Range Correlator. This implementation occurred 4 years in advance of the pre-planned Digital Range Correlator with resulting savings of $13,000 per unit. In total, this VE effort saved the Government over $100 million and the contractor received over $20 million in VE incentives after being reimbursed for approximately $9 million in non-recurring engineering costs. Additionally, since the interim unit was already digital, more savings were generated by building upon the existing design when the Government adopted the pre-planned enhanced Digital Range Correlator.

G. CONCLUSIONS AND NEXT STEPS

VE is a systems engineering tool that employs a structured, innovative problem-solving methodology to reduce cost and improve quality and performance. It develops solutions by eliminating unnecessary functions and establishing new combinations of functions to be more responsive to the needs of the customer. Under DMSMS conditions, the resources required to perform a function are increasing, or are about to increase significantly. Therefore there is a high degree of commonality between the DMSMS risk management process and the VE methodology since VE systematically finds innovative solutions that reduce such costs and increase value.

More specifically, VE is an extremely powerful tool and methodology for (1) identifying a large number of resolution options; (2) evaluating their potential for solving the problem; (3) developing recommendations; and (4) providing incentives for the investments needed for successful implementation. Thus, using the VE methodology provides *greater opportunity* for developing and implementing innovative solutions to DMSMS problems.

As such, VE is ideally suited for use in resolving DMSMS issues. The DMSMS community identifies problems (ideally with plenty of lead time to determine a solution) and the VE tool develops solutions to those problems through function analysis. But the synergies are greater than this. The VE-enabled shared savings with the contractor is also a major factor. This concept provides the contractor with the incentive necessary to make investments that will mitigate DMSMS problems. For each DMSMS resolution option, there is evidence of significant benefits that can be achieved with the use of VE.

Several broad areas of activities should be pursued to institutionalize the relationship between the two communities. For example, better communication among the communities should be encouraged. The DMSMS community should receive training on the VE methodology. The purpose of this training would be to familiarize the DMSMS community with VE methods and capabilities. As a consequence, proactive DMSMS management will routinely include the use of VE practitioners before problems become urgent. Similarly, VE practitioners should more actively interface with the DMSMS community and be better trained in working with DMSMS problems. Potential actions along these lines include:

- Update the DMSMS Guidebook to include a comprehensive treatment of VE and its application to DMSMS.
- Incorporate DMSMS examples into the Defense Acquisition University (DAU) VE distance learning course.
- Incorporate DMSMS into the introductory VE certification training.
- Establish a DMSMS track at the annual VE professional society conference.
- Maintain and strengthen the VE track at the annual DMSMS conference.

- Augment the DAU DMSMS distance learning course to include a section on VE.
- Include VE lessons in appropriate DAU DMSMS classroom material.

There should be extensive outreach to defense contractors and Government and industry program managers as well. Neither DoD logistics program managers nor the logistics support elements of companies with PBL contracts have much experience with VE. Senior DoD leadership should be engaged to bring VE capabilities to the attention of the logistics communities in the DoD Components. Once these PBL customers understand the benefits of using VE in support contracts, they will be likely to promote its use by PBL providers.

Changes to the routine practices and regulations of the DoD contracting community will also help. Currently, the only VE coverage is in the Federal Acquisition Regulation (FAR), which restricts the VE shared savings period to 5 years. Since PBL contracts could last 5 years or longer and DMSMS resolution options should be applicable for a longer period of time as well, consideration should be given to changing the Defense Federal Acquisition Regulations (DFARS) to allow longer sharing periods to provide a better opportunity for contractor investments to achieve an adequate rate of return. Such a change may only be applicable to DMSMS situations. Furthermore, FAR language was written with hardware procurement in mind. While there are innovative ways to use VE with PBL contracts immediately, DFARS changes may be appropriate in the long term.

Finally, greater use of the Value Engineering Program Requirement (VEPR) clause (FAR clause 52.248-1 Alternate II or III) would provide the contractor with incentives to identify DMSMS options that are most advantageous to the Government. The VEPR clause was originally intended to provide the contractor with a small amount of money to study ideas and then submit VECPs. It has evolved into the situation where the DoD funds all of the non-recurring engineering. While a PBL contract normally makes the contractor responsible for DMSMS planning and management, the contractor is not incentivized to look for the low cost solution for the DoD. The VEPR clause can be the spark that encourages the contractor to better optimize from a DoD perspective.

ABBREVIATIONS

AMRAAM	Advanced Medium-Range Air-to-Air Missile
COTS	Commercial-Off-The-Shelf
DAU	Defense Acquisition University
DFARS	Defense Federal Acquisition Regulations
DLA	Defense Logistics Agency
DMSMS	Diminishing Manufacturing Sources and Material Shortages
DoD	Department of Defense
ESSM	Evolved Sea Sparrow Missile
F3I	Form, Fit, Function, and Interface
FAR	Federal Acquisition Regulation
FY	Fiscal Year
IDA	Institute for Defense Analyses
IRU	Inertial Reference Unit
LLM	Launcher-Loader Module
NATO	North Atlantic Treaty Organization
PBL	Performance-Based Logistics
TDP	Technical Data Package
VE	Value Engineering
VECP	Value Engineering Change Proposal
VEP	Value Engineering Proposal
VEPR	Value Engineering Program Requirement

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14. ABSTRACT
Value engineering (VE) is a systems engineering tool that employs a structured, innovative problem-solving methodology to reduce cost and improve quality and performance of Department of Defense (DoD) systems and processes. It develops solutions by eliminating unnecessary functions and establishing new combinations of functions to be more responsive to the needs of the customer. Diminishing manufacturing sources and material shortages (DMSMS) is defined as the loss or impending loss of manufacturers of items or suppliers of items or raw materials. Under DMSMS conditions, the resources required to perform a function are increasing, or are about to increase significantly. Commonality is high between the DMSMS risk management process and the VE methodology since VE systematically finds innovative solutions that reduce such costs and increase value. This paper discusses eight principal DMSMS resolution options and how VE can make a significant contribution to them using real-life examples. Recommendations are made in several broad areas to institutionalize the relationship between the two communities.

15. SUBJECT TERMS
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